Chapter 3
Periodic Inspection

3-1. Purpose of Inspection

a. As discussed in Chapter 2, existing hydraulic steel structures are subjected to conditions that could cause structural deterioration and premature failure. Periodic inspection shall be conducted in accordance with ER 1110-2-100 and ER 1110-2-8157. Periodic inspections on hydraulic steel structures are primarily visual inspections. The inspection procedure should be designed to detect damage, deterioration, or signs of distress to avert any premature failure of the structure and to identify any future maintenance or repair requirements. The periodic inspection should assure that all critical members and connections are fit for service until the next scheduled inspection. Critical members and connections are those structural elements whose failure would render the hydraulic steel structure inoperable. Fitness for service means that the material and fabrication quality are at an appropriate level considering risks and consequences of failure. To be effective, the periodic inspection should be a systematic and complete examination of the entire structure with particular attention given to the critical locations. It should be done while the structure is in use and, to the extent possible, lifted out of the water. Ideally, inspections should be planned to coincide with scheduled dewatering of the structure.

b. If the periodic inspection indicates that a structure may be distressed, a more detailed inspection and evaluation may be necessary. This detailed inspection may require nondestructive and/or destructive testing as discussed in Chapters 4 and 5. The information obtained from the inspections and tests will then be used to perform a structural evaluation as discussed in Chapter 6 and make a recommendation for future action. This chapter will further discuss the visual inspection that should be performed during the periodic inspection.

3-2. Inspection Procedures

The following four primary steps are considered necessary to perform a periodic inspection adequately: preinspection assessment, inspection, evaluation, and recommendations.

a. Preinspection assessment.

(1) To conduct a detailed inspection over the entire hydraulic steel structure on a project is not economical, if at all possible. Prior to inspection, critical areas should be identified to determine which areas of the structure require the most attention (paragraph 3-3). The inspector should prepare by reviewing the design and drawings, previous inspection reports, and all operations/maintenance records since the most recent inspection.

(2) The inspector should review structural drawings to become familiar with the components and operation of each hydraulic steel structure. Locations and details on the structure prone to fracture or fatigue cracking or susceptible to corrosion should be identified. These locations should receive more attention during the inspection. The procedure for identifying critical areas and a checklist of locations (both specific and general) that are susceptible to fracture and corrosion are presented in paragraphs 3-3 and 3-5, respectively, to assist the inspector during the preinspection.

(3) Review of previous inspection reports and operations records will aid in defining occurrence of unusual circumstances or a history of problems. Distress may occur due operational problems (paragraph 2-6) or the occurrence of unusual loads (paragraph 2-7). These events could have imposed high-magnitude stresses and/or a large number of stress cycles, which may cause cracks to develop or members to buckle.

b. Inspection.

(1) Inspection is the activity of examining a structure to ascertain quality, detect damage or deterioration, or otherwise appraise a structure. Particular attention should be given to gate operation (and cathodic protection, if applicable) and the critical locations cited in the preinspection assessment. For the main structural elements, items to consider during inspection include occurrence of cracking or excessive deformation, excessive corrosion, loose rivets, fabrication defects, and damage due to impact from debris. Additionally, all previously reported conditions should be thoroughly inspected. Detailed procedures for inspecting hydraulic steel structures for occurrence of these items are presented in Chapter 4.

(2) Mechanical and electrical components such as seals, lifting mechanisms, bearings, limit switches, cathodic protection systems, and heaters are critical to the operation of hydraulic steel structures and should be inspected appropriately. These components should be checked for general working condition, corrosion, trapped debris, necessary tolerances, and proper lubrication. The structure should also be visually inspected for weld condition and surface defects.

(3) All observations of damage or unusual conditions should be documented in sufficient detail so that all necessary information for a structural evaluation is included and the severity of the condition can be quantitatively compared with previous and future observations.

c. Evaluation. Evaluation of the effects of existing cracks, excessive corrosion, excessive deformation, mechanical problems, weld bead noncompliance with the ANSI/AWS D1.1 standards, and the occurrence of unusual loads must be conducted. This requires qualitative as well as quantitative analysis of inspection data and unusual events reported in previous assessments and evaluations, considering loading and performance criteria required for the existing structure. The periodic inspection is the initial evaluation in the process of determining the structural adequacy of a structure. If surface cracks or fractured members are discovered during the periodic inspections, detailed inspection and evaluation shall be performed for the entire gate. The strength and stability of corroded members should be calculated. Information on evaluation and recommendation procedures is provided in Chapter 6.

d. Recommendations. This task is defined as the process of determining requirements pertaining to frequency of future inspection or remediation of problems, if required. Chapter 6 provides some general information on appropriate recommendations.

3-3. Critical Members and Connections

Critical structural members and connections can be determined from structural analysis of the hydraulic steel structure. This should include local stress concentrations and fatigue considerations. In addition, effects from existing corrosion and reduced weld quality or associated residual stresses should be considered. This analysis will require information pertaining to the existing mechanical properties of the structural material and weld (i.e., strength, toughness, ductility) and the location, type, size, and orientation of any known discontinuities.

a. Critical areas for fracture. Areas in a hydraulic steel structure that may be susceptible to fracture may be determined by considering the combined effect of nominal tensile stress levels and complexity of connection details. Connection details interrupt or change the flow of stress, resulting in stress concentrations; therefore, a moderate level of nominal tension stress occurring at a complex detail (stress concentration) may be amplified to a significant level. To identify critical areas for fracture, determine locations of moderate to high nominal tensile stress levels throughout the structure, identify locations or details where there are significant stress concentrations, and combine the effects of stress level and sensitive details.

(1) Determination of stress levels.

(a) In determining the critical locations for fracture, only nominal tensile stresses are considered since fracture will not occur under constant compressive stress. In contrast, fatigue cracking may occur under cyclic compressive loading when tensile residual stress is present. For example, if a residual tensile stress of 172.4 MPa (25 ksi) exists, a calculated stress variation from zero to 68.95 MPa (10 ksi) in compression would actually be a variation from 172.4 MPa (25 ksi) to 103.4 MPa (15 ksi), which could cause fatigue cracking. Welded members may include high tensile residual stress (near the yield stress in most cases) in the welded region. (EM 1110-2-2105 requires that fatigue design be considered for welded members subject to any computed stress variation, whether it is tension or compression.)

(b) Stress levels in hydraulic steel structures can be determined from a variety of different analytical methods ranging from idealized two-dimensional (2-D) analysis to detailed three-dimensional (3-D) finite element analysis. In most cases, a simple 2-D analysis, such as that used in design, should be sufficient. A more detailed analysis may be required to determine the stress levels in a hydraulic steel structure if the gate has some history of unusual loading (unsymmetric loading or overload). The type of analysis to be performed is dependent on the particular stresses in question and the loading condition. In general, there will be common high-stress areas for a given type of hydraulic steel structure. For example, the following are typical locations of high-tension stress areas common to such hydraulic steel structures as roller, tainter, and lift gates:

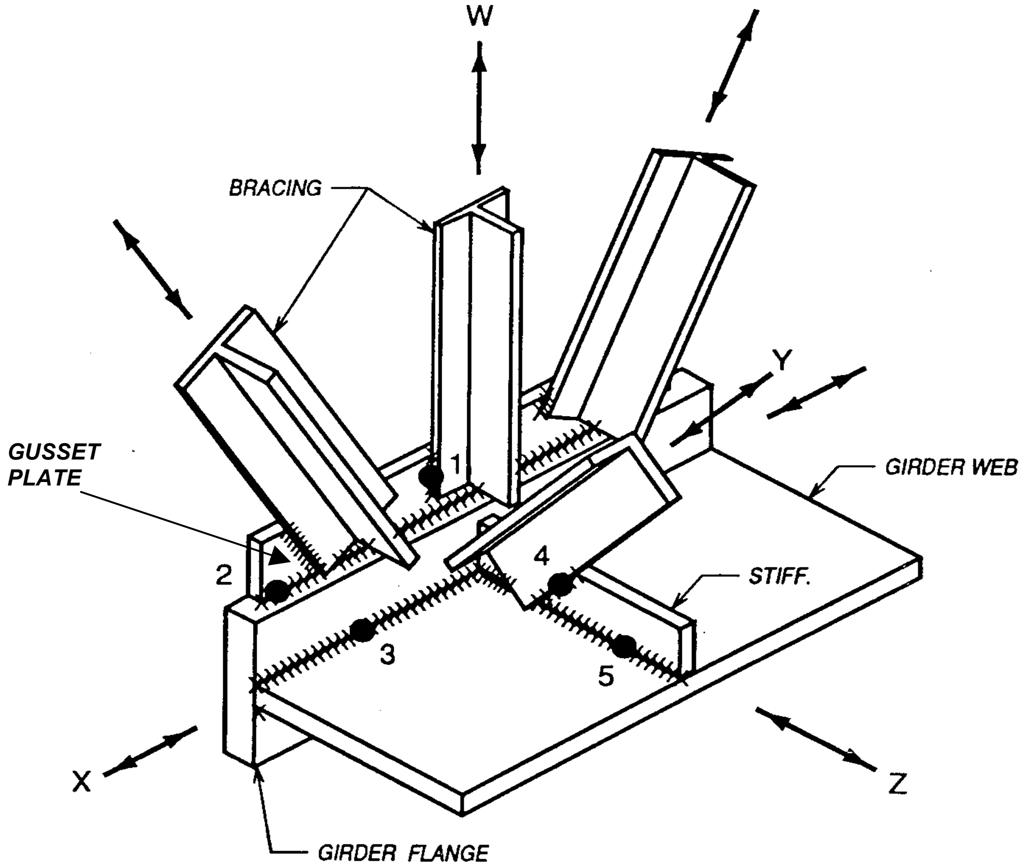
- Roller gates are essentially simply supported and have high tensile stresses at midlength. High stress also occurs at the ends due to large shear forces, unintended flexural restraint, and lifting loads. Additionally, high tension stresses may exist at the junction between the apron assembly and the main tube.

- Tainter gates generally have significant tensile stresses in the downstream flanges at the midlength of the horizontal girders (lower girders are more critical), in the upstream flange of girders, in the outside flange of end frame struts near the girder-strut connections, and where the end frames join the trunnion assemblies (tensile stresses may occur in the end frame due to trunnion pin friction). High tensile stresses will also occur in the upstream flange of skin plate ribs at the horizontal girders.

- Lift gates resist horizontal (due to hydrostatic pressure) and vertical (due to hydrostatic pressure and structural weight) loads. Under horizontal loading, lift gates act essentially as simply supported stiffened plate structures, and significant tensile stresses are likely to occur in the downstream flange at the midlength of the horizontal girders, with highest stresses occurring in the lower girders. High tension stresses may also develop in the upstream flange near the ends of the girders if rotational restraint is imposed due to binding of the guide wheels (from debris or ice collecting at the slot in the pier). Because of displacement under vertical loading, significant tensile stresses may also develop in the bottom of downstream girder flanges and in various connections as discussed in *c* below.

(2) Detail categorization. The purpose of this task is to identify the severity of the stress concentration for various details. Since all details contain some level of stress concentration, a means of determining the relative stress concentration effect of the different connections is needed. For connections made up of welded details, this may be accomplished by determining the appropriate fatigue categories that reflect the severity of the stress concentration introduced by the particular detail.

(a) A complex welded connection will likely consist of several weld details, each with a corresponding fatigue category. For example, consider a gusset plate connection that joins bracing members to the downstream flange of a built-up girder (Figure 3-1). Evaluation of girder flexure includes the longitudinal web-to-flange weld, the attachment of the welded stiffener to the girder, and the attachment of the gusset plate to the girder flange. The fatigue category of the connection is determined by the most critical category detail in the connection. The fatigue category for a particular welded detail is based on the type of weld, geometry



JOINT	MEMBER	STRESS	CATEGORY
1	BRACING FLANGE	W	E at the end of weld
	GUSSET PLATE	W	E at the end of weld
2	GUSSET PLATE	X	E
	GIRDER FLANGE	X	E
3	GIRDER FLANGE	X	B
	GIRDER WEB	X	B
4	INTERNAL BRACING	Y	E at the end of weld
	STIFFENER	Y	E at the end of weld
5	STIFFENER	Z	C
	GIRDER WEB	Z	C

Figure 3-1. Bracing-girder connection

of the detail, and the direction of the applied stress. The general procedure for determining the fatigue category of a welded connection is summarized in the following list. Examples that illustrate this process are provided in (4) and (5) below.

- Locate the main member being examined and define the structural action. At the intersection of two primary members, the structural action of each member must be considered independently and the weld details categorized accordingly. A particular detail may have different fatigue category classifications when the structural action of the different members is considered.

- For each detail, determine the most appropriate example, general condition, and situation (geometry, weld type, loading direction, etc.) as described in Table 2-1.

- Select the appropriate fatigue category as specified in Table 2-1 for each detail.

- For the member and structural action considered, determine the fatigue category for the connection based on the most critical weld detail.

(b) All riveted details, regardless of particular configuration, may be classified as a Category C or D. Welded attachments, tack welds, seal welds, or repair welds that exist in riveted structures, however, may lower the fatigue category of a riveted detail from C or D to Category E or E'. Figure 3-2 shows a fatigue crack starting from a tack weld on a riveted bridge member. The crack initiated at the toe of the tack weld and grew into the riveted plate in the direction perpendicular to the primary tensile stress. Similar damage could occur on any riveted member. Figure 3-3(a) shows fatigue cracks initiating from the ends of welded stiffeners in the end shield of a riveted roller gate. Figure 3-3(b) shows cracks initiating from previous repair welds. In this instance, attempts to strengthen a riveted gate by adding welded stiffening plates created a detail susceptible to fatigue (high stress concentration).

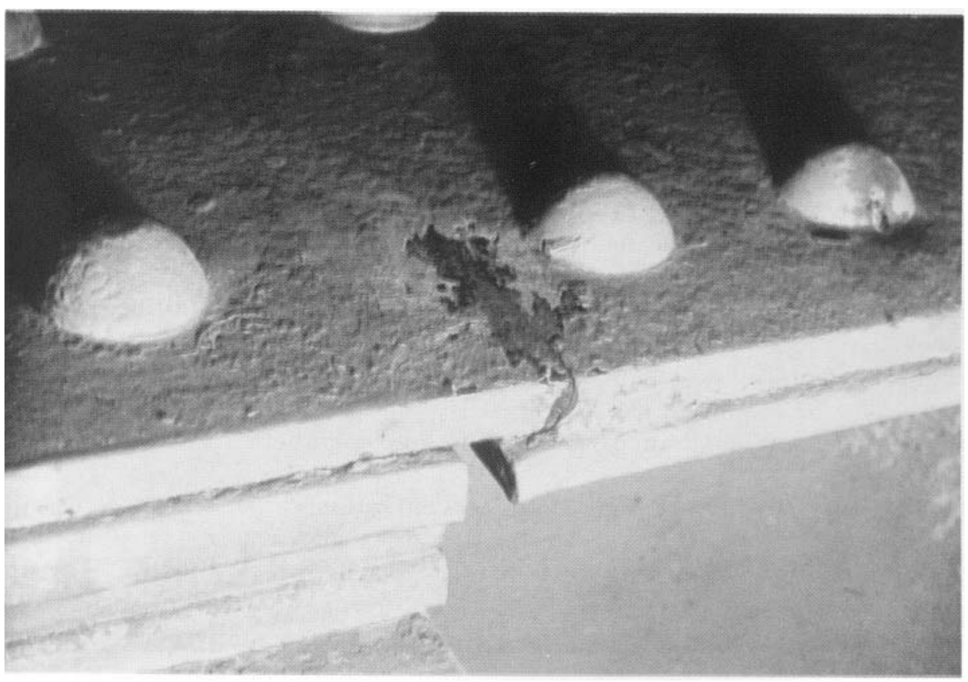
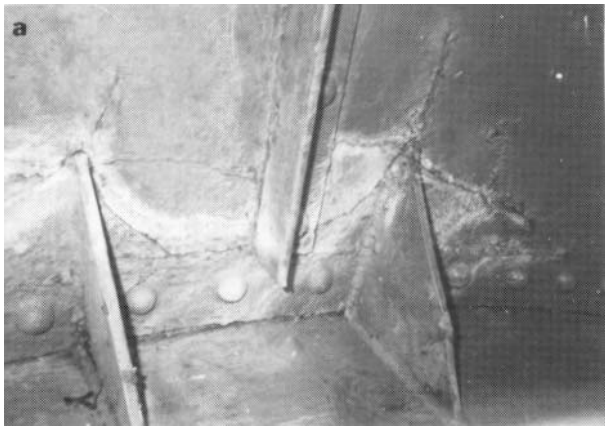


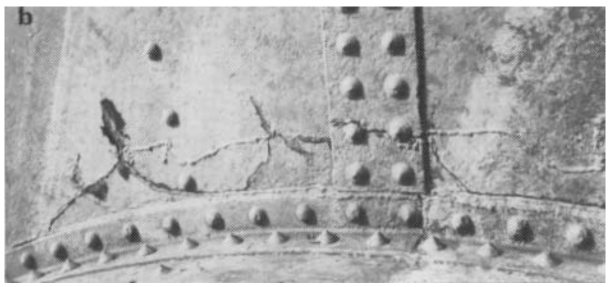
Figure 3-2. Fatigue crack at tack weld on a riveted member

(3) Identifying critical areas: Combining stress and detail.

(a) In determining the most critical areas susceptible to cracking, the combined effect of stress levels and stress concentration must be considered. For a structural component or detail subjected to fatigue loading, the combined effect of the stress range S_r and the stress concentration is reflected in the AASHTO S_r-N curves of Figure 2-1. The fatigue life N is a function of S_r and type of detail (fatigue category); N is lower for higher S_r and more severe stress concentration (lower fatigue category). In a comparison of two or more details, the one with the lowest fatigue life would be the most critical.



a. Fatigue cracks initiating from ends of welded stiffeners



b. Cracks initiating from previous repair welds

Figure 3-3. Fatigue cracks at end of stiffener and at weld repair

(b) This concept may also be applied for a structure under constant load to quantify the susceptibility to fracture. Fracture is most likely to occur at locations where high tension stress and/or severe stress concentration exist. Fatigue cracking due to repeated loading is more likely to occur (will occur sooner) at locations where high S_r and/or low fatigue categories exist. Tensile stress level is analogous to S_r, and severity of stress concentration is analogous to the particular fatigue category. Therefore, fatigue S_r-N relationships can be used to identify the areas most susceptible to fracture in a statically loaded structure by the following procedure. First, determine the fatigue category and nominal stress level for details subject to tensile loads. Second, determine N (with no consideration of fatigue limits) from Figure 2-1 for each detail by substituting the nominal stress level for S_r. Finally, rank the details according to their corresponding N values. The details with the lowest N would be considered most critical.

(c) In this application, N may be viewed as an index that indicates susceptibility to cracking. Index factors for various stress levels and categories are shown in Table 3-1 (lower values are more critical). These factors were derived by dividing N as determined by Figure 2-1 by 10^5. For riveted structures, except where welds exist, the highest stress areas will indicate the most critical locations since all details are Category D for stresses greater than 68.95 MPa (10 ksi).

(4) Fatigue categorization: Girder-rib-skin-plate connection example. To illustrate determining fatigue categories and combining stress and detail for a welded connection, a girder-rib-skin-plate connection that is common to tainter gates is examined. This connection and its fatigue categorization are illustrated in Figure 3-4. Two primary members (the horizontal girder and the vertical rib/skin plate) intersect at this connection.

Table 3-1
Index Factor for Stress and Detail

Stress Level MPa (ksi)	Fatigue Category A	B	B'	C	D	E	E'
41 (6)	1,170	560.0	82.0	214.0	94.0	51.0	18.0
55 (8)	495	238.0	119.0	90.0	40.0	22.0	7.6
69 (10)	250	122.0	61.0	46.0	21.0	11.0	3.9
83 (12)	147	71.0	35.0	27.0	12.0	6.4	2.2
97 (14)	92	44.0	22.0	17.0	7.5	4.0	1.4
110 (16)	62	30.0	15.0	11.0	5.0	2.7	0.95
124 (18)	43	21.0	10.0	7.9	3.5	1.9	0.67
138 (20)	32	15.0	7.6	5.8	2.6	1.4	0.49
152 (22)	24	12.0	5.7	4.3	1.9	1.0	0.37
165 (24)	18	8.8	4.4	3.3	1.5	0.79	0.28
179 (26)	14	6.9	3.5	2.6	1.2	0.62	0.22
193 (28)	12	5.6	2.8	2.1	0.9	0.50	0.18

(a) The first member to be considered is the girder, and the structural action is flexure. Details to evaluate include the longitudinal web-to-flange weld, the attachment of the welded stiffener (if present) to the girder, and the attachment of the rib flange to the girder flange.

- <u>Web-to-flange weld</u>
  Illustrative example: No. 4 (Table 2-1)
  General condition: Built-up member
  Situation: Continuous fillet weld parallel to direction of the applied stress
  Fatigue category: B

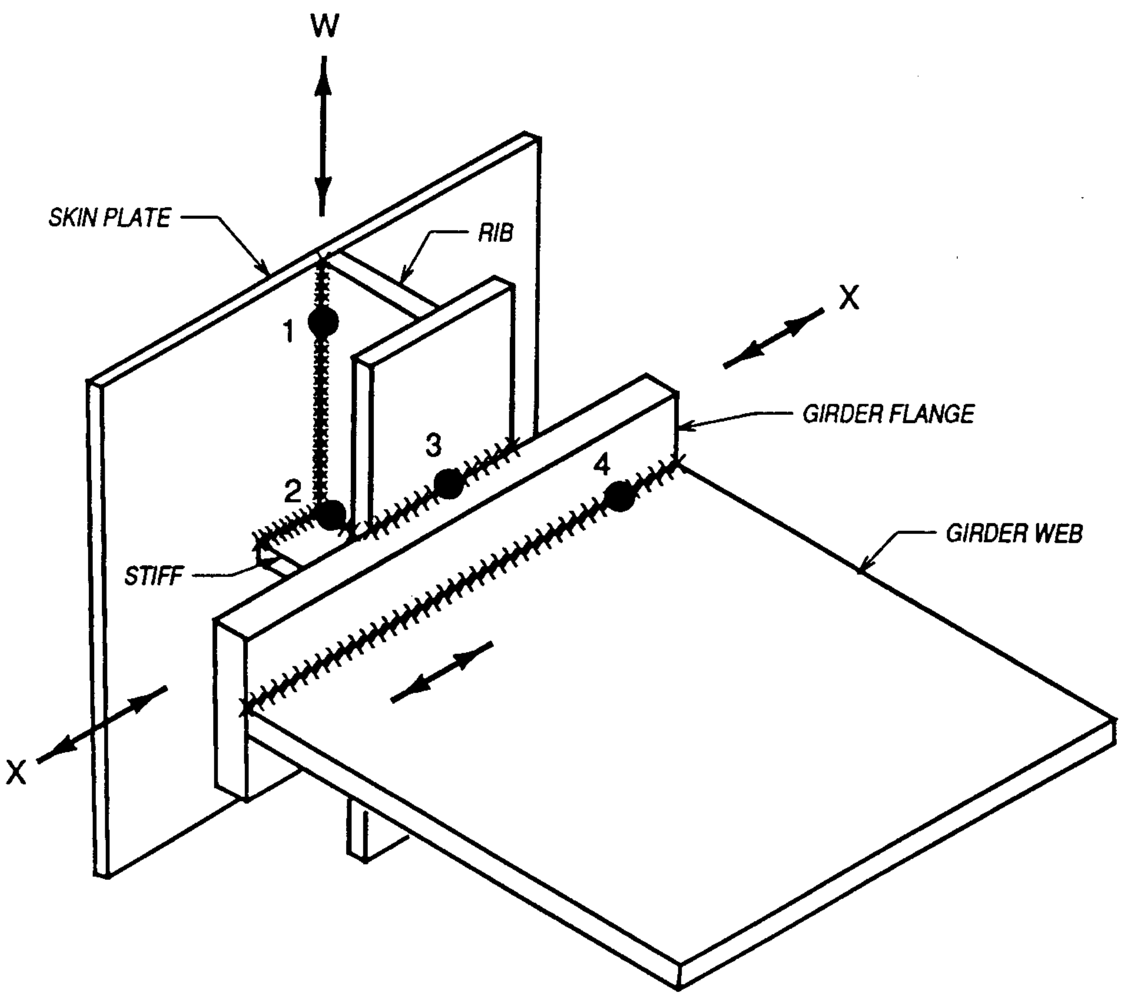
- <u>Welded stiffener</u>

  Illustrative example: No. 6 (Table 2-1)
  General condition: Built-up member
  Situation: Toe of transverse stiffener welds on girder webs or flanges
  Fatigue category: C

- <u>Rib flange to girder flange</u>

  Illustrative example: No. 15 (Table 2-1)
  General condition: Fillet-welded attachments longitudinally loaded
  Situation: Base metal adjacent to details attached by fillet welds
  Fatigue category: C, D, E, or E' depending on weld length (rib flange width) and detail thickness (rib flange thickness)

Based on the most critical weld detail for flexural action of the girder (the rib-to-girder fillet weld), the connection is a fatigue category E or E' depending on the rib flange thickness. This assumes a continuous fillet weld across a rib flange of at least 10 cm (4 in.).



JOINT	MEMBER	STRESS	CATEGORY
1	SKIN PLATE	W	B
	RIB WEB	W	B
2	STIFFENER	W	C
	RIB WEB	W	C
3	RIB FLANGE	W	E or E'
	GIRDER FLANGE	X	C, D, E or E'
4	GIRDER FLANGE	X	B
	GIRDER WEB	X	B

Figure 3-4. Girder-rib-skin-plate connection

(b) The second member to be considered is the vertical rib/skin plate, and the structural action is flexure about the supporting girder. Details to be evaluated include the longitudinal rib-to-skin-plate weld, the attachment of the welded stiffener to the rib and skin plate, and the attachment of the rib flange to the girder flange. Since the structural action for the skin plate and rib is flexure, the rib-to-skin-plate weld is a Category B and the attachment of the welded stiffener to the rib and skin plate is a Category C, similar to the first two details evaluated for the girder. It is not obvious how to classify the fillet weld joining the rib to the girder. For this example, it is assumed that this weld is similar to one at the end of a cover plate that is wider than the flange.

<u>Rib flange to girder flange</u>

Illustrative example:	No. 7 (Table 2-1)
General condition:	Built-up member
Situation:	Welded cover plate wider than flange with welds across the ends
Fatigue category:	E or E' depending on rib flange thickness

Based on the most critical weld detail for flexural action of the rib/skin plate (the rib-to-girder fillet weld), the connection is a fatigue category E or E' depending on the rib flange thickness. If fatigue loading is not a concern, however, only nominal tensile stresses are significant, and these exist at the weld details attached to the skin plate. Under hydrostatic loading, compressive flexural stresses exist in the rib flange. Therefore, considering details subject to nominal tensile stresses that are not cyclic, this connection should be classified as a Category C. For fatigue loading, the connection is Category E or E′.

(5) Fatigue Categorization: Bracing-to-Girder Connection Example. To illustrate determining fatigue categories and combining stress and detail for a welded connection, a bracing-girder connection that is common on miter gates, tainter gates, and lift gates is examined. This connection and its fatigue categorization are illustrated in Figure 3-1. The main member for this connection is the girder, and the structural action is flexure. Details to be evaluated include the longitudinal web-to-flange weld, the attachment of the welded stiffener to the girder, and the attachment of the gusset plate to the girder flange. The web-to-flange weld is a Category B, and the attachment of the welded stiffener to the girder is a Category C, similar to the first two details evaluated for the girder connection presented in (4) above.

<u>Gusset-plate-to-girder-flange weld</u>

Illustrative example:	No. 16 (Table 2-1)
General condition:	Groove-welded attachments longitudinally loaded
Situation:	Base metal adjacent to details attached by groove welds with a transition radius less than 50 mm (2 in.)
Fatigue category:	E

Based on the most critical weld detail (the gusset-plate-to-girder-flange weld), the connection is a fatigue category E.

(6) Combining stress and detail example. The process of combining stress and detail for tainter gate connections described in (4) and (5) above will be discussed in general terms. For this example, it is assumed that fatigue loading is not a concern.

(a) For the girder-rib-skin-plate connection, the rib-to-girder weld was determined to be a Category E or E' for girder flexure (assume a Category E). This connection is located at each vertical rib on the upstream girder flange along the length of the girder. Without fatigue loading, only nominal tensile stresses should be considered. Along the length of the girder near midspan, the flexural stresses due to hydrostatic loading are compressive in the upstream flange. Therefore, this connection is not critical near midspan. However, near the end frames, the flexural stress in the upstream flange is tensile with the highest stresses nearest the end frames. Assuming a structural analysis shows that the stress in the upstream flange near the end frames is about 103 MPa (15 ksi), the index factor for the rib-to-girder weld (Category E) is approximately 3.3 (Table 3-1). For rib/skin plate flexure, the most critical weld detail (stiffener attachment) under tensile stresses is a Category C. Under hydrostatic loading, compressive flexural stresses exist in the rib flange. Assuming that a structural analysis shows that the maximum tensile stress in the skin plate is 68.9 MPa (10 ksi), the index factor is 46.

(b) For the bracing-to-downstream-girder-flange connection, the most critical weld detail (the gusset-plate-to-girder-flange weld) is a fatigue category E. Under hydrostatic loading, tensile flexural stresses exist in the downstream girder flange at areas away from the end frames with the highest stresses at midspan. Assuming that bracing is located at midspan, and the stress in the downstream girder flange at midspan is about 124.1 MPa (18 ksi), the index factor for the gusset-plate-to-girder weld is 1.9 (Table 3-1).

(c) Based on the stress levels in this example, the most critical areas for inspection are at the gusset-plate-to-girder-flange weld on the downstream girder flange at midspan of the girder (index factor 1.9) and at the rib-to-girder weld on the upstream girder flange, near the end frame where the upstream flange of the girder is in tension (index factor 3.3). Although it depends on the size and geometry of individual girders, the lower girders generally have the highest stress levels and are, therefore, more critical.

*b. Critical areas for corrosion damage***.** Chapter 2 discusses several types of corrosion that can occur on hydraulic steel structures. Corrosion can occur at any location on a structure, but certain areas are more susceptible to corrosion damage than others. Sensitivity to corrosion is enhanced at crevices, areas where dissimilar metals come in contact, areas subject to erosion, and areas where ponding water or debris may accumulate. Other areas often susceptible to corrosion are those where it is difficult to apply a protective coating adequately, such as at sharp corners, edges, intermittent welds, and rivets and bolts.

(1) Galvanic corrosion occurs at the contact surfaces of dissimilar metals or between steels with different electrochemical potential. For example, ASTM A7-67 steel is more electrochemically active than ASTM A588/A588M steel (a low-carbon weathering steel containing copper) and would corrode when coupled with A588/A588M steel. There may also be a potential difference between rivet steel and the adjoining plate or angle. If different steels have been used in the construction or repair of a structure, these locations should be inspected for galvanic corrosion.

(2) Other corrosion-susceptible areas are those where abrasion may occur. This type of corrosion may occur around moving parts such as at the guide wheels on vertical lift gates or at the trunnion assemblies or chain locations on tainter gates.

(3) Webs of the structural members on many gates, bulkheads, and valves are oriented horizontally or radially, providing corrosion-susceptible locations where ponding or debris accumulation may occur. To prevent ponding, the webs of these members are penetrated by drain holes. The hole locations can be corrosion-susceptible areas, especially if they are covered with debris. Areas where ponding may occur and the location of web drain holes should be determined prior to inspection.

(4) Seals on hydraulic steel structures are common locations of corrosion damage. Seals are subject to crevice corrosion between the contact surfaces of the structure and seal, galvanic corrosion if the seal plate is of a dissimilar metal to that of the structure itself, or erosion corrosion if abrasive sand and silt particles are passing through.

(5) Other areas susceptible to corrosion include heater locations (promotes oxidation) and the normal waterline (wetting and drying promotes corrosion).

(6) Areas with loose rivets or bolts are potential locations for crevice corrosion or fretting corrosion if the base components of the connection are loose.

(7) In addition to consideration of the previously described susceptible areas, certain findings during the physical inspection may indicate possibilities of corrosion. Generally, any failure of the paint system is an indication of underlying corrosion. A widespread failure of the paint system may indicate general corrosion resulting in a slow, relatively uniform thinning of the base metal. Moreover, some localized pitting corrosion may be present. If there is a localized failure of the paint system, localized corrosion may be occurring. Paint failure where the edges of two or more surfaces contact, such as at the edge of a rivet head or at the edge of an angle riveted to a plate, may indicate crevice corrosion. Paint failure near electrical connections may indicate stray current corrosion. If the paint failure is patterned or preferential in appearance, it may be due to filiform corrosion under the paint or to mechanically assisted corrosion, either fretting or erosion corrosion.

c. Critical areas for other effects. As discussed in Chapter 2, many factors other than nominal stress levels, severity of stress concentration, or corrosion aspects may contribute to the deterioration of a structure. These include effects of material thickness (affects residual stress, toughness, and constraint) and fabrication (i.e. weld quality, tack welds, intersecting welds, or poor accessibility), operational vibration or overload, displacement-induced secondary stress, and concentrated loads. The following paragraphs discuss some of these concerns.

(1) Details fabricated from thick plate sections and/or with large amounts of welding in a concentrated area are susceptible to cracking. Trunnion assemblies on tainter gates and lifting connections on all structures are examples. Locations where weld quality is poor are particularly susceptible to cracking. In welded joints there is a potential for many types of discontinuities, as illustrated in Chapter 4. Intersecting welds are often located on hydraulic steel structures at uncoped stiffeners and where diaphragm webs frame into girder webs and flanges.

(2) Where vibrational loads have been reported, components subjected to high-frequency flow-induced vibration may be critical. The lower sill of tainter gates and valves, the apron assembly of roller gates, and the end shield of roller gates are examples. Furthermore, any location where previous damage (buckling, plastic deformation, cracking, extreme corrosion) has been reported should be considered critical.

(3) Additional considerations are locations where extreme stresses occur in components subject to unforeseen secondary or displacement-induced stresses. One example is at the diaphragm-flange-to-girder-flange connections on welded lift gates. Under vertical loading, the horizontal girder flanges displace in a vertical plane similar to a uniformly loaded simple beam. The ends of diaphragm flanges are forced to rotate with the displaced girder flanges, which causes a large tensile force on one edge of the diaphragm; the girder flange rotation is greatest near the ends of the girders (Figure 3-5). Another example is at connections between a roller drum cylinder and the end shields (Figure 3-6). The rigidity of the connection prevents the movement of one component against the other. When a hydraulic steel structure is being opened or closed or when high-velocity water flows by the structure, relative local displacement may occur between two rigidly connected components and induce high stresses. Concentrated loads may induce high local stresses and/or displacements between connected components. Concentrated loads occur at support locations on all structures (i.e., trunnion assembly of gates and valves, end posts of lift gates, and end disks of roller gates), lifting connections, and areas where skin plate ribs are attached to horizontal girders on a tainter gate.

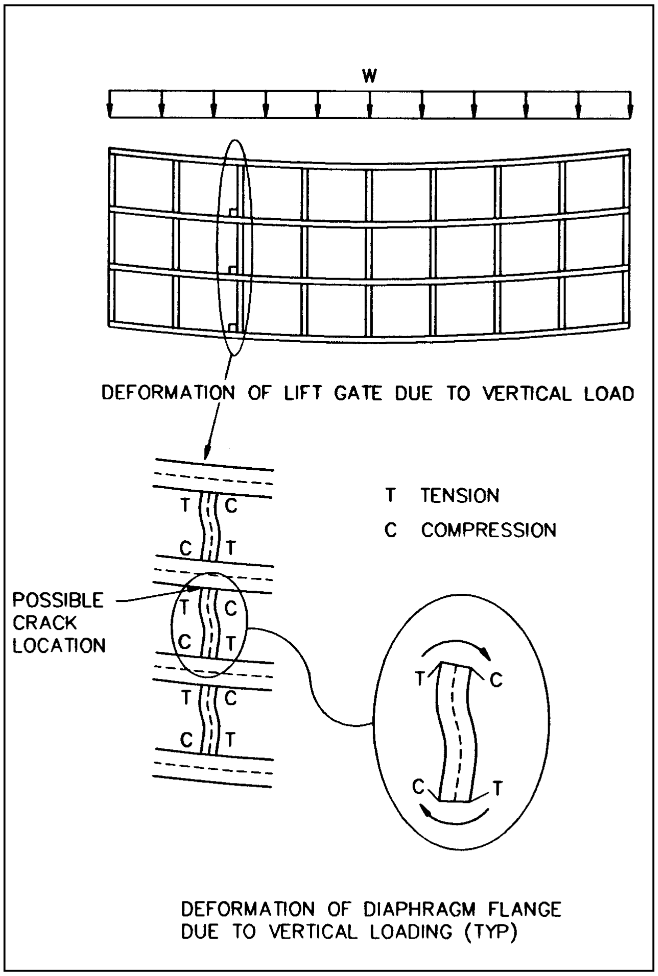


Figure 3-5. Distortion-induced high-stress location

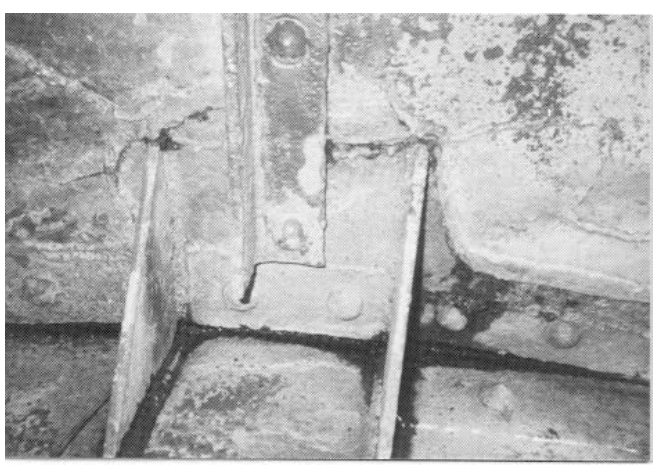


Figure 3-6. Fatigue crack at weld repair on roller gate end shield

3-4. Visual Inspection

a. Visual inspection is the primary inspection method and shall be used to inspect all critical elements as determined according to paragraph 3-3. A visual inspection is hands-on and requires careful and close examination. The inspector should look closely at the members and connections and not just view them from a distance. Inspectors should use various measuring scales, magnifying glasses, and other hand tools to identify, measure, and locate areas of concerns. Boroscopes, flashlights, and mirrors may be necessary to inspect areas of limited accessibility. Weld gauges should be available to check the dimensions of weld beads. Critical areas should be cleaned prior to inspection, and additional lighting should be used when necessary.

b. Inspection methods other than visual inspection may be used for the periodic inspection of hydraulic steel structures, if necessary. These methods, discussed in Chapter 4, include dye penetrant, magnetic particle, or eddy-current methods for inspection of cracks, and ultrasonic methods for inspection of cracks or corrosion loss.

3-5. Critical Area Checklist

For the periodic inspection of any hydraulic steel structure, a critical area checklist should be developed prior to inspection as part of the preinspection assessment discussed in paragraph 3-2. Critical areas are likely common for a given type of hydraulic steel structure; however, detailed lists may be individually structure dependent.

a. *General*. Based on the discussion in this chapter and Chapter 2, the following common areas should be inspected on all hydraulic steel structures:

(1) All nonredundant and/or fracture critical components. These typically include main framing members and lifting and support assemblies.

(2) Locations identified as susceptible to fracture or weld-related cracking as outlined in paragraph 3-3*a*.

(3) Corrosion-susceptible areas as outlined in paragraph 3-3*b* (normal waterline, abrasion areas, crevices, locations with dissimilar metals).

(4) Lifting connections or hitches. These are subjected to high concentrated loads, are often of welded thick-plate construction, and are fracture critical. The lifting chain or cable used to lift the gate is also critical.

(5) Support locations: trunnion (tainter gate, valves), end post (lift gate), top anchorage and pintle areas (miter gate), and end disk (roller gate) assemblies. These are subjected to high concentrated loads, are often of welded thick-plate construction, and are fracture critical.

(6) Intersecting welds. These occur at uncoped stiffeners and diaphragm web-to-girder welds.

(7) Previous cracks repaired by welding. Figure 3-6 shows an example of cracks redeveloped at weld repairs.

(8) Locations of previous repairs or where damage has been reported. This includes buckling or plastic deformation, cracking, or corrosion.

b. Roller gates. Additional critical areas common for roller gates include the following (Figure 3-7):

(1) Attachments and connections at midspan (high tensile stress, stress concentration).

(2) The apron assembly connection to the roller (high stress, stress concentration).

(3) Connections between the roller drum cylinder and the end shields (displacement-induced stresses).

c. Tainter gates. Additional critical areas common for tainter gates include the following (Figure 3-8):

(1) Girder-rib-skin-plate connection on the upstream girder flange near the end frames and the bracing-to-downstream-girder-flange connection near midspan (critical tension stress/detail combinations).

(2) Connections of main framing members such as the girder-to-strut connection (fracture critical, high moments).

(3) Seal lip plate if it is fabricated from stainless steel or other dissimilar metal (galvanic and/or crevice corrosion).

d. Lift gates. Additional critical areas common for lift gates include the following (Figure 3-9):

(1) Horizontal girder-to-end-box-girder connection and the bracing-to-downstream-girder-flange connection near midspan (critical tension stress/detail combinations).

(2) The ends of diaphragm flanges where attached to downstream girder flanges (displacement-induced stresses).

e. Miter gates. Additional critical areas common for miter gates include the following (Figure 3-10):

(1) Horizontal girder-to-miter and quoin post connections (thick plates, high constraint, high stress).

(2) The ends of diaphragm flanges where attached to downstream girder flanges (high stress, stress concentration).

(3) Connections at ends of diagonal members (high stress, fracture critical).

3-6. Inspection Intervals

The maximum time interval between periodic inspections of hydraulic steel structures is established in ER 1110-2-100. Visual inspections should also be performed if unusual loading situations occur. Such situations include barge impact, earthquake, excessive ice load, increase in frictional forces between seals and embedded plates, and movement of the supporting monoliths. Additional detailed inspections may be required to pursue concerns resulting from the periodic inspections or investigate reported distress from lock personnel. If discontinuities exist, fracture mechanics concepts can also be applied to determine appropriate inspection intervals as discussed in Chapter 6.

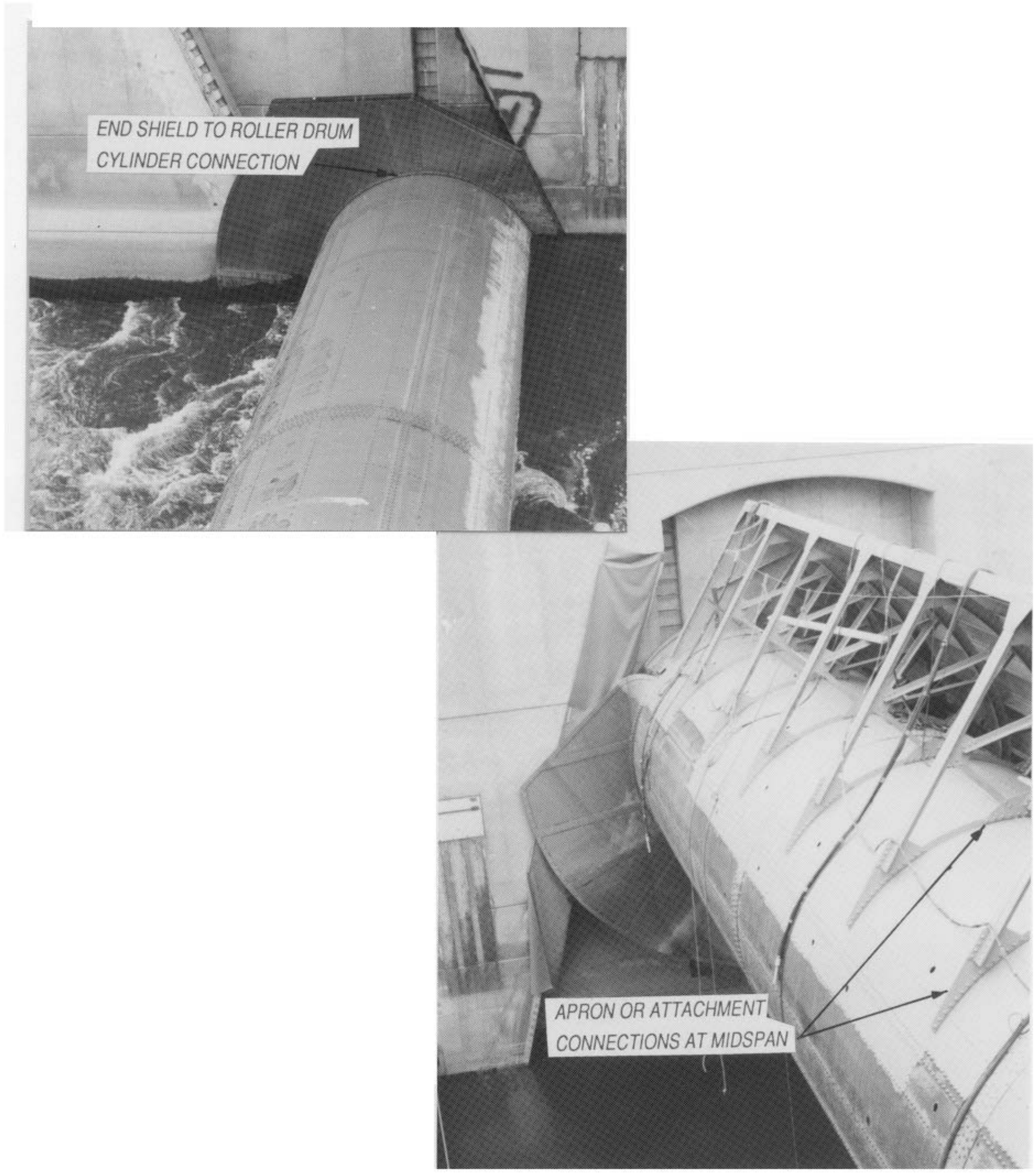


Figure 3-7. Critical areas for roller gates

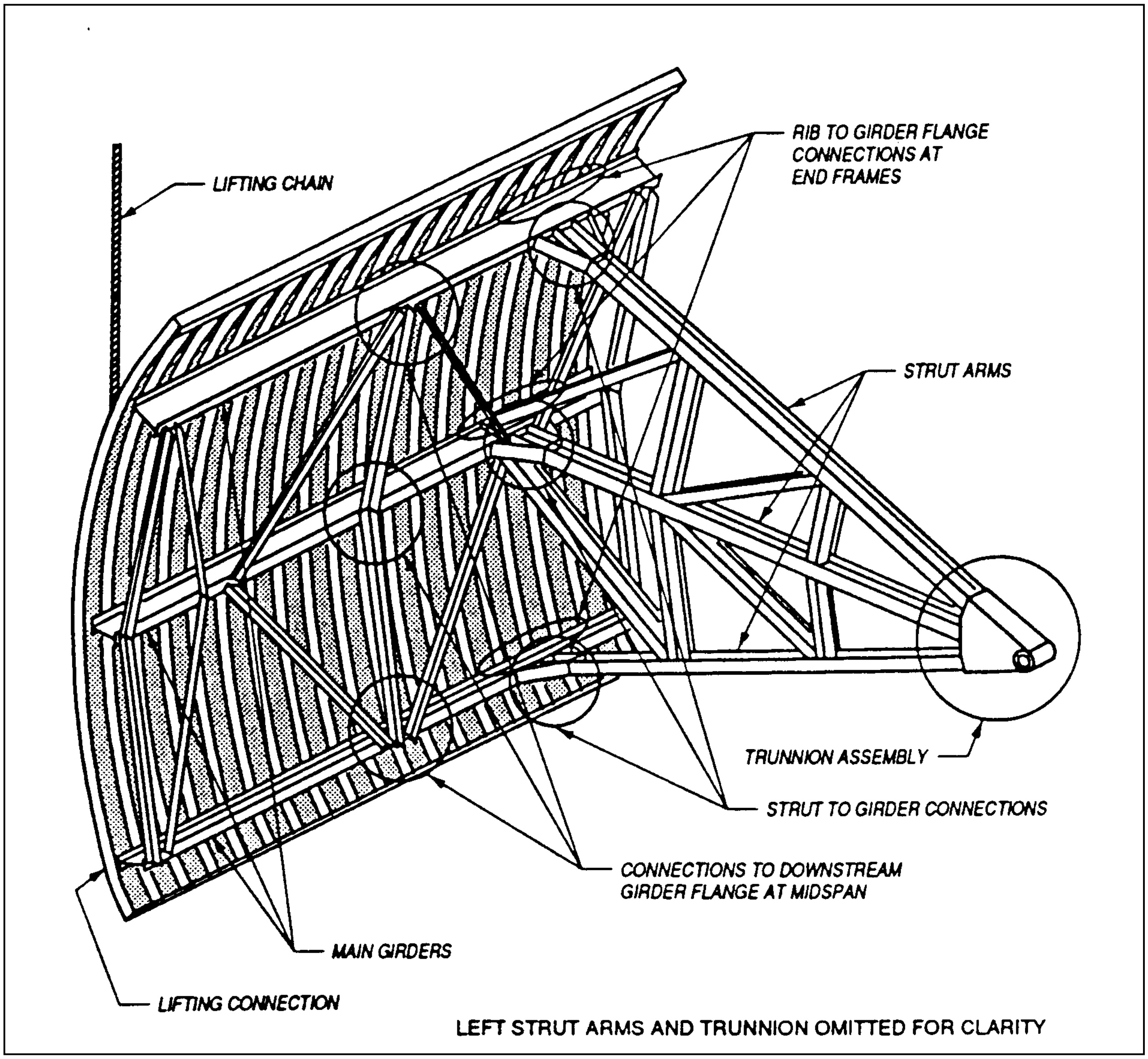


Figure 3-8. Critical areas for tainter gates

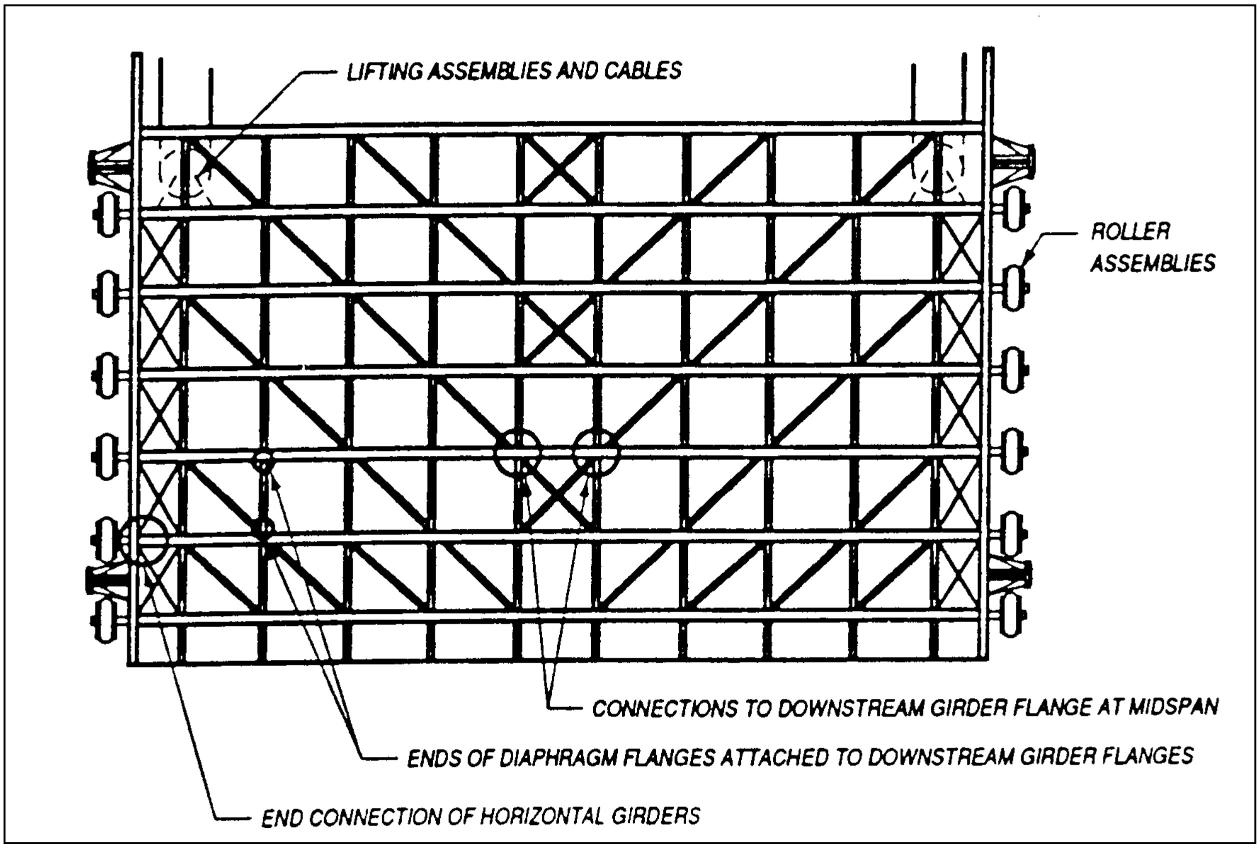


Figure 3-9. Critical areas for lift gates

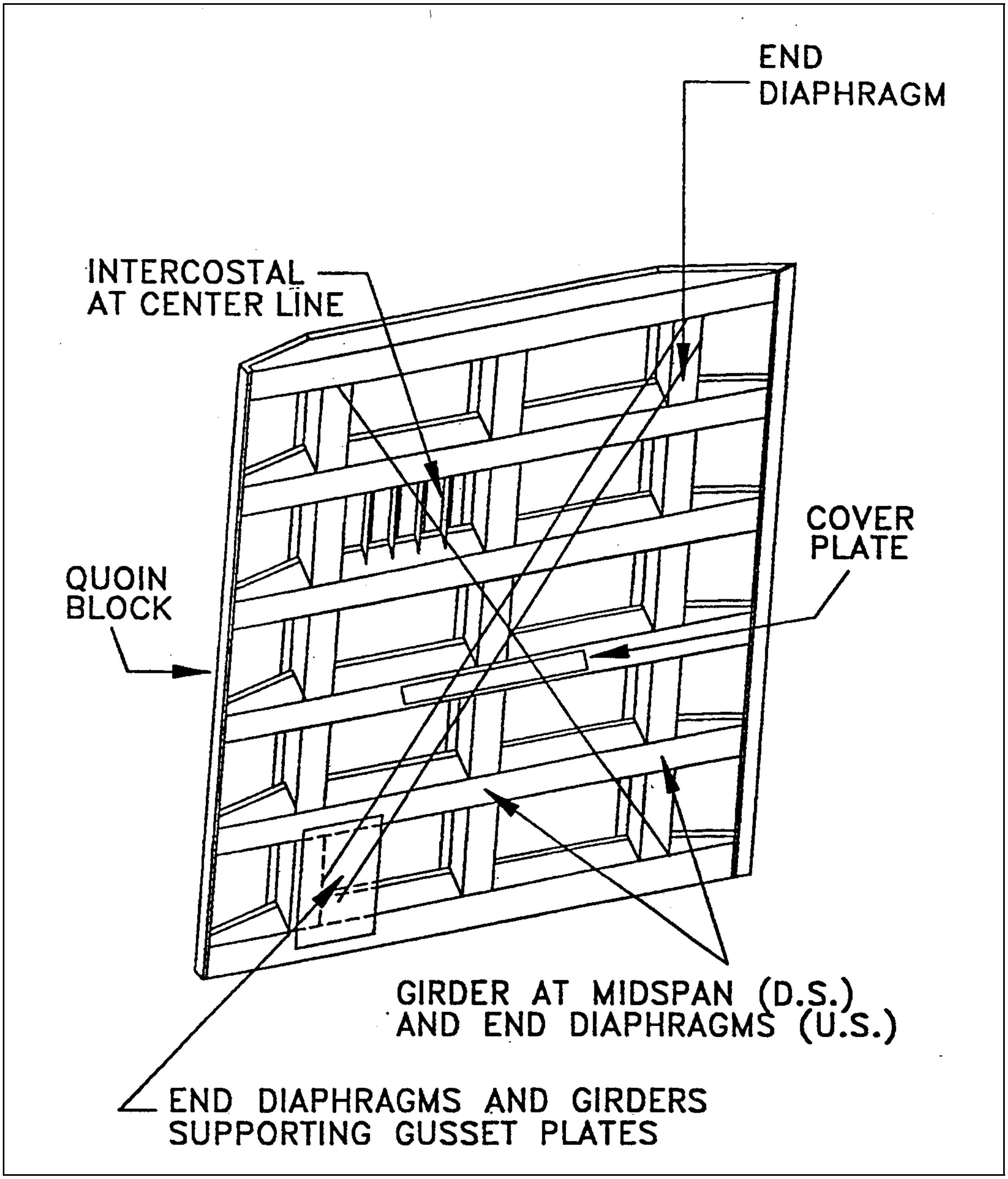


Figure 3-10. Critical areas for miter gates